



ABSTRACT

The sustainability of meat protein supply for mass consumption faces growing threats due to the interplay of environmental degradation, population growth, and dietary changes among the expanding global middle class. As the feasibility of meeting the growing demand for meat becomes increasingly uncertain, it becomes imperative to offer alternatives to conventional livestock farming.

This article delves into the pressing matter of food security and extends its focus to address the sustainability challenges posed by conventional meat production. It underscores the immediate need for technological advancements in the livestock farming industry that must be done apart from mechanisation, advocating for the consideration of alternative meat proteins.

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NAVIGATING THE PATH TO FOOD SECURITY THROUGH ALTERNATIVE MEAT PROTEINS

by **Anis Farhana Amran**

In an earlier PNBRI publication, ‘Rethinking Self Sufficiency as a Measure of Food Security’, we underscored the importance of developing a comprehensive national food security strategy that considers the multidimensionality of food insecurity. Subsequently, the goal of this edition is to highlight one of the key enablers towards greater food security – namely, technology.

To recap, the World Food Summit in 1996 defined food security as the state in which every individual consistently possesses both the physical and economic access to sufficient, safe, and nutritious food that fulfils their dietary requirements and preferences for a healthy and active life (Food and Agricultural Organization (FAO) 2008). The FAO has identified four main dimensions of food security: physical availability of food, economic and physical access to food, food utilisation or nutrition, and the stability of the other three dimensions over time. More recent literature has even proposed a six-dimensional framework, that includes agency and sustainability as essential components to food security (Clapp et al. 2022).

Among the prevalent discourses globally towards achieving food security is about the role of innovation and technological advancement in achieving the goals for each dimension. While the use of technology in agriculture is typically associated with mechanisation in farming practices to improve crop yields, this article delves deeper into a specific dimension of innovation and technology in the laboratory context — the production of alternative meat.

Problem Statement: Conventional Meat on the Brink of Extinction

Conventional meat proteins – such as poultry, beef, and fisheries – are on the brink of extinction, after decades of unsustainable farming practices associated with industrialised scale livestock rearing and overfishing. The primary issue with traditional and industrial scale livestock farming in the way the world has gotten used to revolves not least around its negative environmental impacts.

The prospect of supplying meat for mass human consumption is being jeopardised by the intersecting challenges of environmental degradation and population growth. This challenge will be exacerbated by shifts in nutrition preferences towards protein-rich foods, necessitating increased meat production. This calls for technological interventions within the livestock farming industry that goes beyond mechanisation; alternative (meat) proteins may just be the answer.

Demand-Side Pressures: Escalating Meat Consumption Worldwide is Propelled by Population Expansion and Shifts in Nutritional Preferences

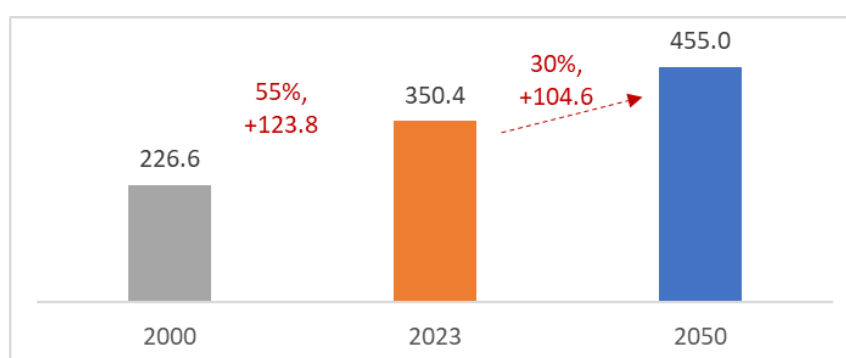


Figure 1: Global Total Meat Consumption, in 2000, 2023, and 2050F (million tonnes); Sources: OECD-FAO Agricultural Outlook 2023-2032(OECD-FAO Agricultural Outlook 2023-2032 2023), UN FAO Global Meat Consumption, 1961 to 2050 (UN Food and Agriculture Organization (FAO) 2013a) and PNBRI Analysis

The most authoritative and publicly available cross-country data is the OECD-FAO Agricultural Outlook Database, which tracks meat consumption, primarily (1) beef and veal, (2) pork meat, (3) poultry meat, and (4) sheep meat. As shown in Figure 1, global meat consumption is expected to increase further by around 30% by 2050 from its current level (or 1.2% on an annually compounded basis), following the significant growth of about 55% observed since 2000 (or 3.4% on an annually compounded basis).

Zooming into the nearer future, the OECD-FAO projects a 7% rise in global meat consumption by 2030 (Figure 2(a)). Juxtaposing this global trend to Malaysia's, the estimated growth rate in Malaysia is nearly three times that of the world (Figure 2(b)).

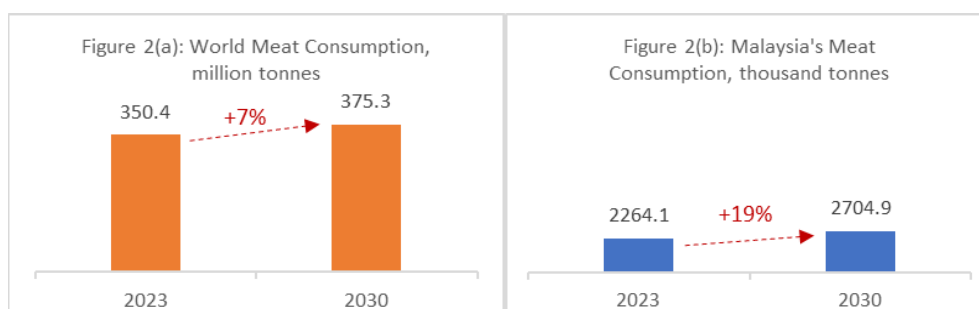


Figure 2: Total meat consumption, 2023e and 2030f, for (a) World total (in million tonnes), and (b) Malaysia total (in thousand tonnes); Sources: OECD-FAO Agricultural Outlook 2023-2032^[2], UN FAO Global Meat Consumption, 1961 to 2050^[3] and PNBRI Analysis

This surge in meat consumption has been widely attributed to two pivotal factors, namely the rising global population, and the nutritional transition phenomenon, influenced by increasing prosperity in societies worldwide. Nutritional transition is defined simply as the process of “modernisation, urbanisation, economic development, and increased wealth leading to predictable shifts in diet” (Harvard T.H. Chan School of Public Health 2024). This phenomenon can partly be illustrated by the disparity in meat consumption between the developed and developing world. Over the last 20 years, consumption of beef and veal, pork, poultry, and sheep in the developing world has grown at a rate of 1.2% annually, while consumption in the developed world has contracted by 0.3% annually over the same period.

The more mouths to feed, the more meat we ‘need’...

According to UN estimates, both the global and the Malaysian population are expected to grow by approximately one-fifth of their levels by 2050. This projected surge represents a significant demographic shift, which could have an impact on societal dynamics and resource demands, including the demand for meat.

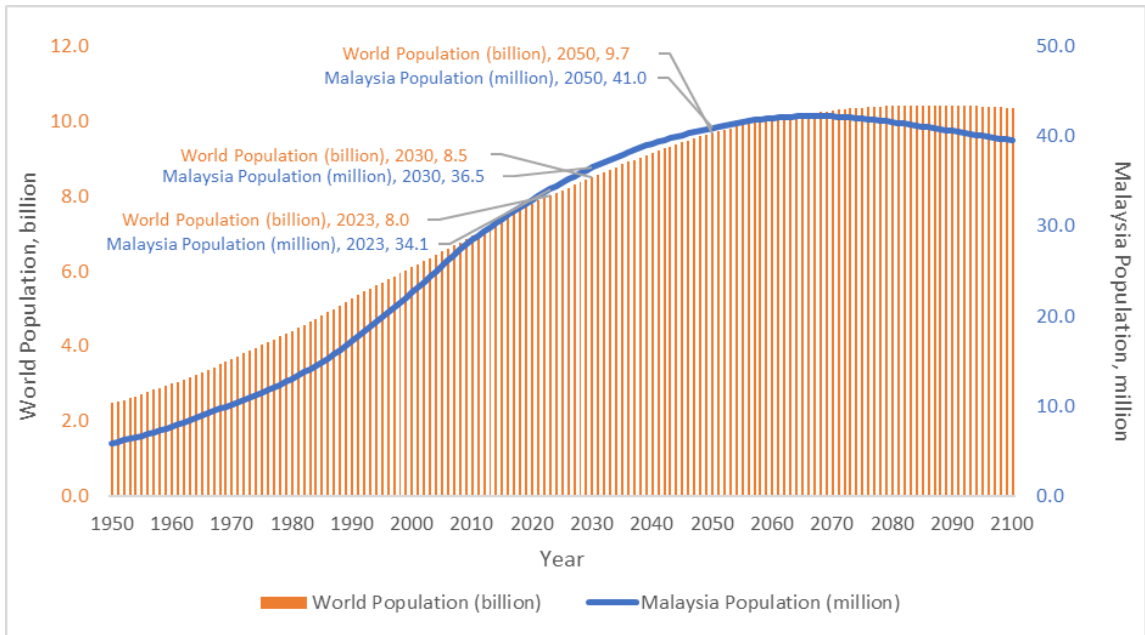


Figure 3: World Population (billion) and Malaysia Population (million), estimates and forecasts (1950-2100); Sources: *United Nations 2022 Revision of World Population Prospects*(United Nations Population Division 2022) and PNBRI Analysis

The pronounced impact of population growth on the growth of meat consumption is evident if we examine the trajectory in the last three decades between 1990 and 2020.

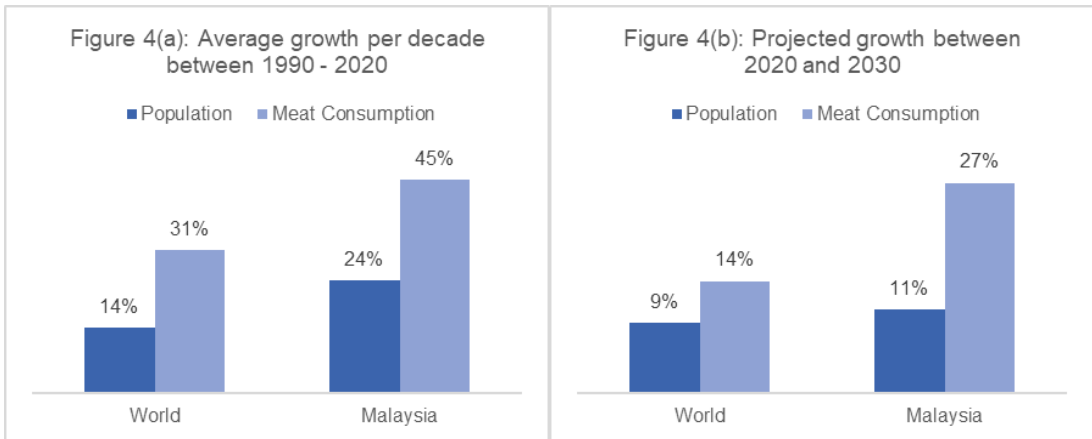


Figure 4: Growth in Population versus Growth in Meat Consumption (per decade, 1990 – 2020 vs 2020 - 2030), for the World and Malaysia, (%); Sources: *United Nations 2022 Revision of World Population Prospects* (United Nations Population Division 2022), *OECD-FAO Agricultural Outlook 2023-2032*(OECD-FAO Agricultural Outlook 2023-2032 2023) and PNBRI Analysis

As shown in Figure 4(a), a growing population corresponds with a greater-than-proportionate increase in meat consumption worldwide. More specifically, over the last three decades, global meat consumption grew about twice as fast as world population per decade. The same can be said for Malaysia where meat consumption increased nearly twice as fast as the Malaysian population per decade, on average.

...and the more wealth we make, the more meat we 'want'

Figure 4(b) raises a slightly more interesting question – while global meat consumption growth is expected to slow down compared to previous decades, relative to population growth, Malaysian meat consumption growth is expected to accelerate significantly relative to population growth.

This nearly tripling of the growth in meat consumption relative to population growth suggests a more nuanced interplay between population and meat consumption; in other words, socio-economic factors are at play in Malaysia. However, this phenomenon is not unique to Malaysia. Not only does meat consumption rise with a growing population but it also rises on a per capita basis, indicating a substantial shift in the nation's dietary consumption patterns towards meat consumption – as predicted by the nutrition transition theory.

The 'nutrition transition' is a term that originates from the medical sphere, referring to a model proposed in the late 1990s "to describe the large shifts that have occurred in human diets and activity patterns" (Popkin and Eng 2022), particularly in the field of studies related to nutrition-related noncommunicable diseases such as obesity and hypertension. While the concept aims to describe generalised patterns of change in dietary patterns, it most popularly refers to the inevitable shift observed within the developing world from a state of famine to a state of rising incomes and abundant food supplies. As a result, populations transition from traditional diets to 'Western style' diets typically constituting higher energy-dense food and animal products.

The observed increase in meat consumption worldwide and in Malaysia can be attributed in part to this dietary transition¹ caused by rising levels of wealth ("The Protein Puzzle: The Consumption and Production of Meat, Dairy and Fish in the European Union," n.d.). Wealthier consumers typically opt for nutrient-dense diets that include more meat and dairy products, while avoiding root crops and cereals (Drewnowski 2023).

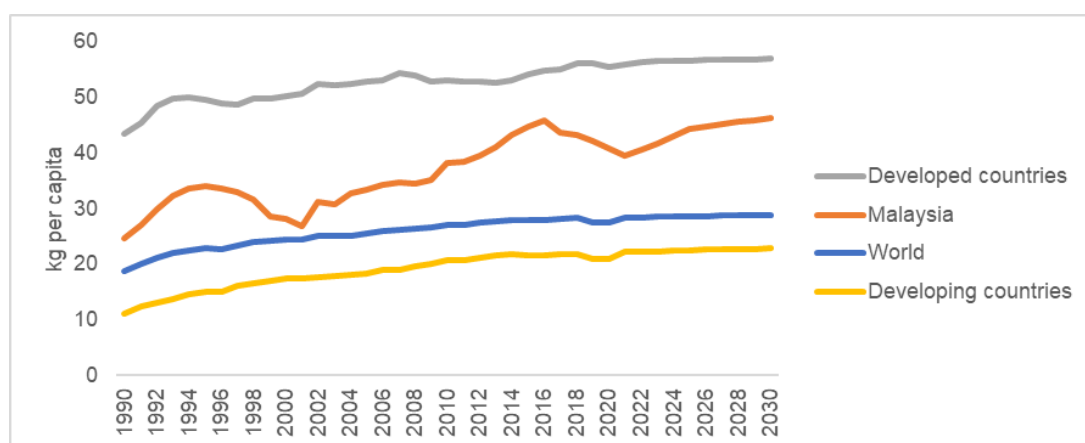


Figure 5: Total meat consumption per capita, 1990-2030 (kg per capita); Sources: OECD-FAO Agricultural Outlook 2023-2032 (OECD-FAO Agricultural Outlook 2023-2032 2023) and PNBRI Analysis

Figure 5 (above) depicts a stark contrast in meat consumption between developed and developing countries. Developed countries currently consume roughly 2.5 times more meat per capita than developing countries and twice the global average.

¹ While nutrition transitions are strongly driven by the rise in income, it does not necessarily imply a better nourished diet. It sometimes ends up contributing to overnourishment ("The Protein Puzzle: The Consumption and Production of Meat, Dairy and Fish in the European Union," n.d.), which is also a form of malnutrition.

As countries like Malaysia transition from upper-middle-income to high-income and developed nation status, there is a discernible trend in its per capita meat consumption - where it is fast aligning with the consumption levels observed in developed countries. Malaysia's per capita meat consumption is expected to double by 2030, compared to the levels recorded in the 1990s, indicating not only increasing affluence, but also its profound impact on dietary habits, specifically on meat intake. As countries like Malaysia progress economically and become more urbanised (United Nations Population Division 2018), more people are expected to be able to afford a meat-rich diet.

It is worth noting that in the specific case of Malaysia, even before its current trajectory towards a high-income economy in the early 1990s, meat consumption per capita has consistently been significantly higher than that of developing countries on average. This could be a reflection of our food systems, including price and market structures such as quotas and subsidies – a worthy exploration in future articles.

Demand for meat in a nutshell: soaring demand thanks to natural and behavioural forces

In short, the global surge in meat demand is driven by unyielding natural and behavioural forces. Population growth raises challenges in sustainable production of meat proteins for mass consumption, while individual incomes pose a unique challenge. Given the voluntary nature of dietary changes, it is difficult to limit preferences for meat-dense meals. To promote well-being and environmental consciousness, governments must adopt nuanced approaches, such as policy nudges and awareness campaigns.

While these transitions present challenges, they also provide opportunities for improved food utilisation and nutritional intake. Constricting voluntary dietary shifts risks undermining efforts to address undernourishment, emphasising the importance of balanced strategies that consider both nutrition and sustainability.

Supply-Side Issues: Heightened Production of Conventional Meat is Exacerbating Environmental Harms

Harm #1: The rise in demand for traditional meat will result in increased and intensified land use for livestock farming



Figure 6: Livestock farming occupying agricultural land, requiring vast land for animals to graze, on top of growing feed crops and farm infrastructure; *Image source: Ajuntament de Valencia*



Figure 7: Cultivated meat in labs, requiring significantly less land and offers easier monitoring throughout production; *Image source: Adobe Stock*

Figures 6 and 7 serve as compelling visuals, highlighting the stark contrast in land requirements between traditional livestock farming and the process of producing lab-grown meat. Livestock farming utilises approximately 77% of the world's agricultural land, while contributing less than 20% to the global calorie supply (Ritchie 2017). In other words, the sheer resource requirements for livestock farming may simply not commensurate with its yield, highlighting potential inefficiencies in land and resource allocation. The conclusion is clear: a significant increase in agricultural land use worldwide will be required to accompany the rise in meat consumption worldwide as earlier discussed.

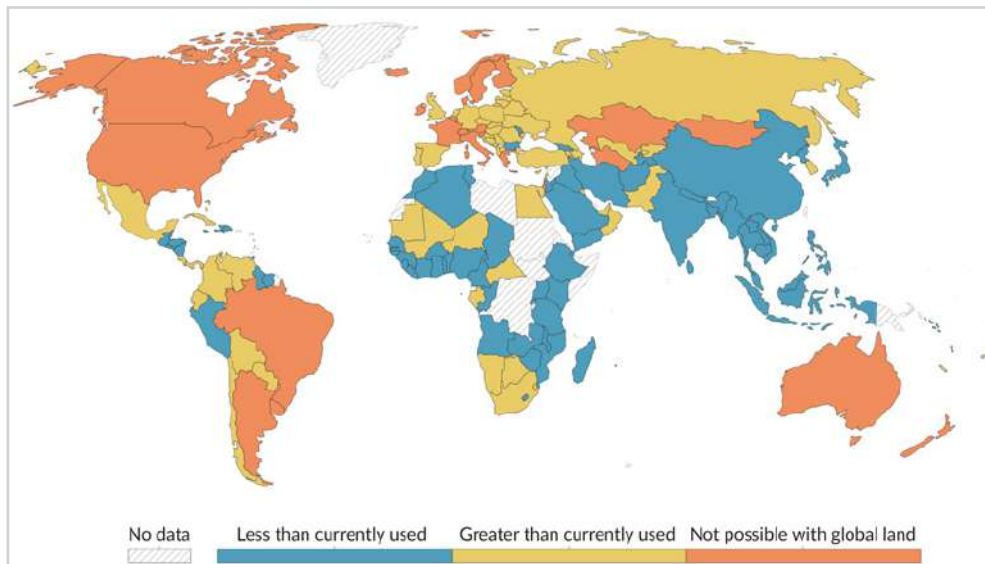


Figure 8: The percentage of global habitable land area needed for agriculture if the total world population was to adopt the average diet of any given country; Sources: *Human appropriation of land for food: The role of diet* (Alexander et al. 2016); *Our World in Data* (Ritchie 2017).

As depicted in Figure 8, countries highlighted in orange exhibit dietary patterns that, if universally adopted, would exceed the available global land resources. For instance, if the daily diet of every individual worldwide were to align with the American dietary patterns, it would require a 38% expansion of land use beyond the global capacity (Ritchie 2017). In anticipation of dietary shifts towards meat-dense diets in countries marked in yellow and blue, it is foreseeable that their average diets will shift to becoming more meat-dense, increasing the strain on agricultural land.

Harm #2: Rising demand for traditional meat will result in higher GHG emissions

Livestock farming also poses a significant environmental threat through greenhouse gas emissions (GHG), which account for over 11% of global GHG emissions. Reviewed estimates report as high as almost 20% of potential emissions (Blaustein-Rejto and Gambino, n.d.), primarily through the release of methane (CH₄) and nitrous oxide (N₂O). Ruminants such as cows emit methane during digestion, and livestock manure undergoes anaerobic decomposition, releasing methane and nitrous oxide. This is even before accounting for land-use changes associated with animal feed production, which contribute to deforestation, releasing stored carbon, and reduce the Earth's ability to absorb GHG.

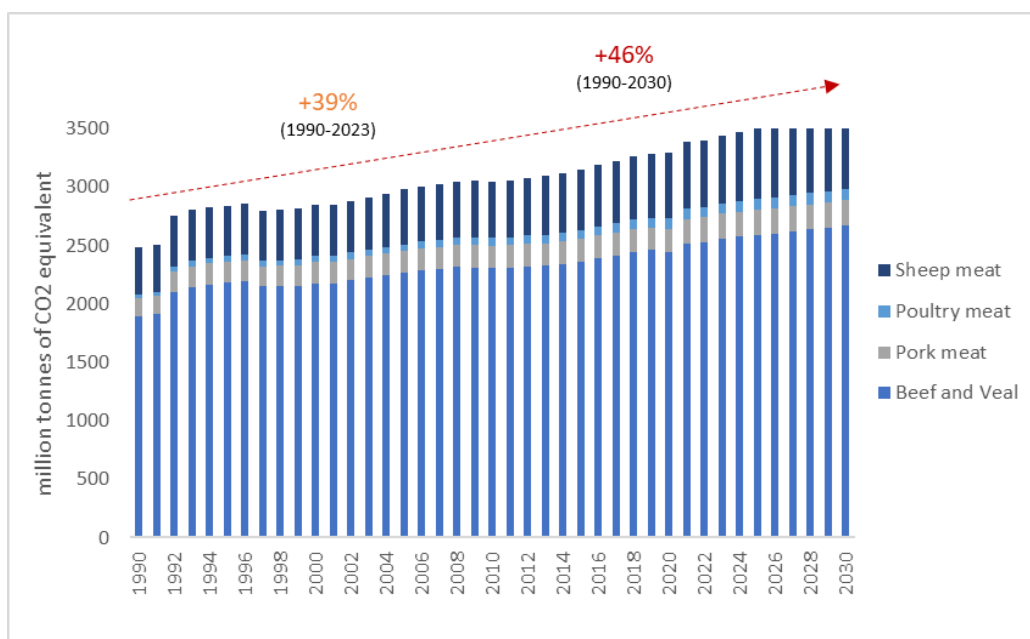


Figure 9: Direct GHG emissions by type of meat production, World, 1990-2030 (million tonnes of CO₂ equivalent); Source: OECD-FAO Agricultural Outlook 2023-2032 (OECD-FAO Agricultural Outlook 2023-2032 2023) and PNBRI Analysis

Global conventions among world leaders have unanimously agreed that future GHG emissions must be urgently reduced. At the current rate of emissions, temperatures are forecasted to rise by about 3.7°C by the year 2100. There could also be up to 4 million sq km of new deserts around the world (Harvey 2021). These will affect at least one-third of global food production by way of extreme temperature rise, drastic changes in rainfalls, and extreme aridity (Harvey 2021).

Figure 9 shows that direct GHG emissions from global livestock production have surged by nearly 40% from 1990 to 2023. Projections indicate that this upward trend will continue, with levels anticipated to reach almost 50% higher than 1990's levels by 2030. Notably troubling is the substantial contribution of beef and veal meats production to these emission levels, despite accounting for only one-fifth of the average global meat consumption (UN Food and Agriculture Organization (FAO) 2013a). Since the 1990s, emissions from beef and veal production have consistently accounted for more than 70% of overall meat production. While technologies and practices have been adopted to significantly reduce GHG emissions from livestock production, widespread adoption remains a considerable challenge.

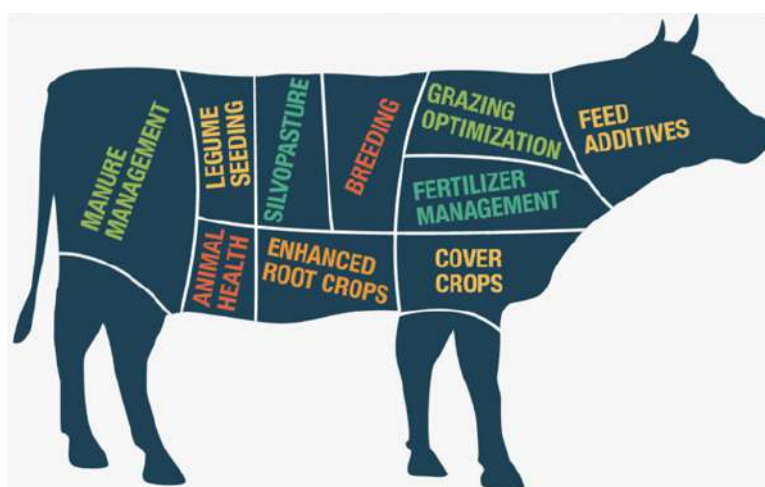


Figure 10: An Illustration on "How to Cut Beef's Carbon Footprint"; Source: *The Breakthrough Institute* (Blaustein-Rejto and Gambino, n.d.)

As illustrated in Figure 10, reducing GHG emissions in livestock farming, particularly in beef production, involves specialised interventions. While widespread adoption of efficient practices can reduce emissions by up to 30% (UN Food and Agriculture Organization (FAO) 2013b), persistent barriers to their implementation remain. This necessitates a kind of "reset" for the entire industry – involving science, policy, and changes in human behaviour. To this end, it becomes imperative for us to explore alternative production methods of meat that are fit for human consumption whilst continuing to pursue sustainable methods in the production of protein sources.

Alternative Meats as An Emerging Solution

There is an urgent need to provide an alternative to traditional livestock farming systems while nudging consumers towards more environmentally friendly alternatives, beyond plant-based proteins which may continue to stress the environment. In this context, alternative proteins, or more specifically alternative meat, is emerging as an increasingly viable option.

Alternative proteins refer to a wide range of protein sources, including soy- or plant-based proteins that have been incorporated in traditional meals for centuries in certain regions. However, in recent years, there have been a growing number of alternatives in the market that closely mimic the taste and texture of meat, which is our focus in this article. These alternatives primarily replicate conventional meat, namely beef and veal, pork, poultry, and sheep (Food and Agriculture Organisation of the United Nations (FAO) and OECD 2023).

There are multiple variations of alternative proteins, one of which is the alternative meat variant, which is currently available in three general types depending on the production method and protein sources. These include **plant-based meats**, **meats derived from fermentation**, and **cultured meat**.

With technological advancement, **plant-based alternatives** have become more sophisticated. Some vegetable burgers, for instance, achieve a medium-rare appearance that is similar to traditional burgers by incorporating beet juice, creating a "bleeding" effect in the patty (EUFIC 2023a). **Nanka**, a Malaysian start-up, produces jackfruit-based burger patties and a range of other protein food ("Jackfruit Power: Nanka's Goal to Feed Plant-Based Fast Food to Malaysians" 2022). **Ultimateat** is another growing Malaysian company which produces wheat and soy-based meat products, specialising in meat alternatives. At present, Ultimateat products marketed are mostly plant-based meat, but they are planning to launch their mycoprotein-based meat soon.



Figure 11: Ultimateat's existing plant-based products in Malaysia's market; Source: Ultimateat

Globally, **Beyond Burger** is one of the pioneering market players based in the US, producing patties that are made from peas, mung beans and rice ("Go Beyond: Beyond Meat," n.d.). Some other popular examples of plant-based meat include **Impossible Foods**, **Gardein**, and **Morningstar** (Bandurski 2023).

Advancements in the fermentation technology have also brought rise to **fermentation-derived meat** which is produced using either (i) biomass fermentation or, more recently, (ii) precision fermentation. Biomass fermentation uses fungi which have high-protein content and can rapidly grow to efficiently make large amounts of protein-rich food. The microorganisms that reproduce through this process are themselves ingredients for alternative proteins. A globally popular example is **Quorn**, which grows filamentous fungi, mycoprotein, into their end meat products – meat-free burgers, sausages, and chicken nuggets (GFI, n.d.). Locally, **Ultimateat** is also transitioning from mainly producing traditional plant-based meat products to making mycoprotein-based meat alternatives.

A more recent breakthrough making waves in large parts of Europe and North America are startups such as **New Culture**, **Change Foods**, **ONEGOBio** and **Every** which use precision fermentation technology that uses microorganisms to produce specific functional ingredients – in this case, cheese, eggs, and meat patties. The process produces customisable, complex organic molecules from microbes using precision biology (Hinds 2020). It introduces gene sequences of animal proteins in organisms like yeast, which use these "production instructions" to generate large amounts of the target proteins (EUFIC 2023b). Some precision fermentation companies are exploring the use of bacteria.

Cultured meats, on the other hand are produced by cultivating animal cells in vitro, outside of the animal's body, and subjecting them to controlled conditions in a laboratory to foster growth and development into muscle tissue. Hence, the process includes very minimal animal involvement compared to conventional meat production methods, despite still being derived from actual animals.



Figure 12: Cultured chicken kebab skewers sold at Huber's Butchery;
Image source: Good Meat



Figure 13: Huber's Butchery & Bistro in 22 Dempsey Road, Singapore 249679; Image source: World Gourmet Summit

While there are numerous labs that cultivate meat globally – including in Malaysia – Singapore was the first country to approve the sale of lab-grown meat in December 2020 (Begum 2022), followed by the US recently in June 2023. Halal and Kosher labels are obtainable if the cells are originated from processes that adhere to religious standards (Douglas 2023). The first ever cultured chicken approved for sale three years ago in Singapore is by food start-up **Eat JUST** and is sold as kebab skewers at Huber's Butchery, selling at \$18.50 (Begum 2023).

The table below summarises these three types of alternative meats:

Type	Inputs	Typical Process	End Products
Plant-based meat	Wheat, soy, legumes, jackfruit	Extraction of natural proteins from raw materials followed with "extrusion" process using heat to texture the proteins	Plant-based burger patties, sausages, and nuggets
Fermentation-derived meat	Microbial proteins (FAO 2021), usually mycoprotein – a type of fungi	Biomass fermentation or precision fermentation	Fungal-based meat substitutes
Cultured meat	Animal cells cultured in a controlled environment	Cultivation of animal cells in vitro, outside of the animal's body in a controlled lab environment	Lab-grown meat, including beef, chicken, pork, and other cultured meat products.

Figure 14: Types of Alternative Meats Alternative Proteins: Types, Utilisation and End Products; Source: *Alternative Proteins: Types, Utilisation and End Products* (Sources: Good Food Institute (GFI) (GFI 2023), European Food Information Council (EUFIC) (EUFIC 2023a) and PNBRI Analysis)

There are also other alternative proteins available in the current horizon that are derived from **plants**, **insects**, and **algae**, but is not the focus of this article.

Type	Typical Input and Process	End Products
Plant proteins	Derived from plant-based proteins like soy, grains, nuts, and legumes	Soy products like tofu, tempeh, and edamame. Grains such as quinoa, oats, and barley. Nuts and seeds like almonds, chia seeds, and hemp seeds. Legumes such as beans, lentils, and chickpeas
Insect proteins	Derived from edible insects, which are rich in protein, vitamins, and minerals	Insect-based protein bars , cricket flour , and insect-based snacks
Algal proteins	Derived from algae, which are rich in protein and offer a sustainable alternative to traditional seafood	Algal-based seafood alternatives , including fish fillets and shrimp

Figure 15: Other Types of Alternative Proteins: Alternative Proteins: Types, Utilisation and End Products; (Sources: Good Food Institute (GFI) (GFI 2023), European Food Information Council (EUFIC) (EUFIC 2023a) and PNBRI Analysis)

Looking to the Future for Alternative Meats

Currently, only plant-based meat alternatives derived from soy and wheat are widely available in the market. Lab-grown cultured meats still have some way to go to commercialisation, mainly due to the size of investments and food and health regulations globally. Only Singapore and US have allowed cultured meat to be sold to consumers today (Benson and Greene 2023).

Fermentation-derived meat may soon replace plant-based meat, while cultivated meat still have a long way to go

Brands like **Beyond** and **Impossible Burgers** have diligently altered their nutritional compositions to replicate that of meat's as close as possible (Frezal, Nenert, and Gay 2022), partly contributing to the popularity of plant-based meats due to its presumed health and environmental benefits. However, researchers found that protein absorption from plant-based meat is lower than from real meat (Lennon 2022). A study published in the Journal of Agricultural and Food Chemistry discovered that during an in-vitro digestion, the absorption of plant-based protein was comparatively lower than that of protein derived from chicken. It concluded that the quality of plant-based meat should be evaluated not only by its texture, but also by its nutrition – which is arguably far more important.

This may be the push for some alternative meat companies to transition from plant-based meats to mycoprotein-based meats. The PNBRI team's recent visit to the **Ultimateat** factory in Malaysia found that "Wheat and soy were the earlier generations, mycoprotein is the next generation of our meat alternatives". Numerous studies have concluded that mycoprotein may be healthier than real meats due to its remarkable nutrition composition, which includes high biological value protein, dietary fibre, minerals, and vitamins, as well as a significantly low saturated fatty acids content (Ahmad et al. 2022). Its healthy nutritional profile is evident in its effectiveness in sustaining blood insulin levels and modulates human digestive process while also improve blood cholesterol level (Ahmad et al. 2022). Nevertheless, studies also acknowledge the possibility of individuals developing allergies upon consuming mycoprotein (Finnigan et al. 2019).

Other than its nutritional benefits, mycoprotein is the more ideal option compared to soy and wheat because sourcing them is more efficient (Ultimateat, 2024). For countries with tropical climates like Malaysia, soy and wheats still need to be imported. Mycoprotein fungi, on the other hand, can be farmed locally and harvested in a factories using large vats called fermenters.



Figure 16: Fungi being fermented in the large vat in a factory producing mycoprotein for Mycorena, a biotechnology company based in Sweden; Image source: New Food

Achieving Price Parity: A Possibility in The Near Future

For as long **Ayamas** offer RM9 for 450g of chicken balls, the prospects of the average Malaysian spending RM30 for 300g of Quorn's mycoprotein-based meatballs continue to be unlikely. As such, achieving price

parity will likely continue to be one of the most important barriers against widespread adoption of alternative meats in countries heavily involved in livestock farming as part of its political economy. Nevertheless, the Good Food Institute (Good Food Institute, 2022) projects that cost per-unit for meat alternatives could soon be reduced with scale and efficiency.

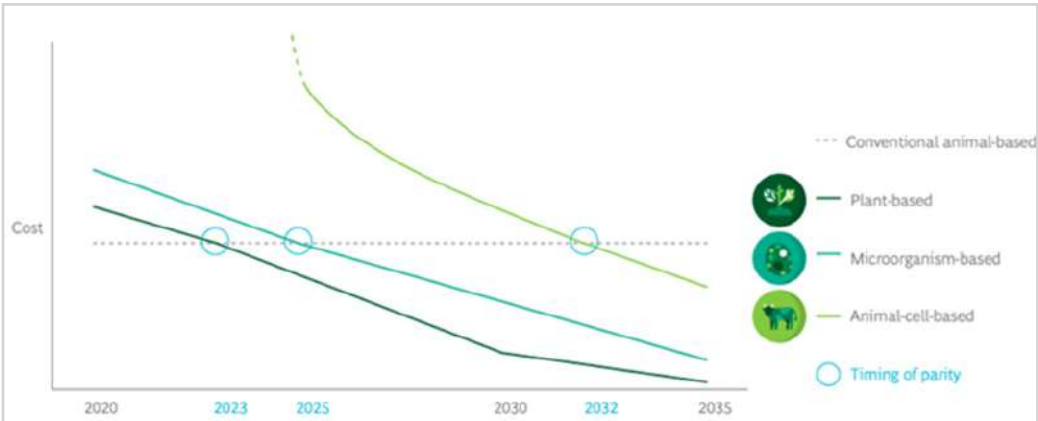


Figure 17: Relative timing of cost parity for alternative proteins with realistic taste and texture; Sources: Blue Horizon and BCG analysis, expert interviews; industry report; Note: This analysis includes illustrative data for US and EU; variations by product group and geographic area are omitted for clarity

Ultimateat, for example, aims to penetrate the market with prices even lower than conventional meat. Currently, its plant-based nuggets are priced at RM13.60 for 340g, which is comparable to off-the shelf chicken nuggets made from real chicken like Ayamas and Ramlee. One worth-quoting success story in plant-based meats achieving price parity would be **Vegeworld’s** Vegetarian Lamb - although its texture and nutritional value may not be comparable to real lamb, it sells for RM37.45 per kg, roughly half of the price of real lamb.

Conclusion

Adopting alternative proteins offers a more sustainable and efficient way to produce protein. All three plant-based, fermentation-derived, and cultured meat require significantly less land, water, and energy to produce than traditional meat (GFI, n.d.; UNEP 2023; GFI, n.d.). They also emit lower GHG emissions (GFI, n.d.; UNEP 2023; GFI, n.d.). With a lower environmental footprint, alternative meats require fewer resources to meet the global demand for meat, thus contributing to long-term food security.

Aside from efforts to promote more sustainable livestock farming practices, this author argues that meat alternatives offer tangible solutions to help ensure meat supply for mass consumption. It may be worthwhile for Malaysia, under the direction of Ministry of Agriculture and Food Security (MAFS), to learn from Singapore’s proactive approach towards food security, which was the first country to allow the sale of cultivated meat. Meat alternatives should no longer be perceived as “rocket science” or only viable for vegetarians. Before we know it, this author projects that meat alternatives will make its way into our daily menus and represent a sizeable investable market. Policymakers, regulators, researchers, and the industry should work closely and concertedly to speed up the adoption of meat alternatives in Malaysia.

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